CALIFORNIA DIVISION OF MINES AND GEOLOGY

FAULT EVALUATION REPORT FER-94

October 19, 1979

1. Name of faults.

Calaveras (Hollister segment), and "Buena Vista Road" faults.

2. Location of faults.

Hollister 7.5 - minute quadrangle, San Benito County (figure 1).

3. Reason for evaluation.

Part of 10 - year evaluation program.

4. References.

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5. Review of available data, airphoto interpretation, field checking.

The Special Studies Zones (SSZ) of 1974 depicted on the Hollister 7.5 - minute quadrangle (figures 1 and 2) were based on fault traces mapped by Nason (1971), Radbruch (1968), Rogers (1973), and Taliaferro (1948). Faults shown on the SSZ Map and to be discussed in this fault evaluation report (FER) include the Calaveras fault zone, San Andreas fault zone, and a northeast trending fault informally referred to in this report as the "Buena Vista Road" fault.

CALAVERAS FAULT ZONE

West Branch Calaveras Fault

The location and activity of the west branch (main trace) of the Calaveras fault is well documented (Nason, 1971; Rogers, 1969, 1973;Rogers and Nason, 1967, 1971) (figure 2). Historic fault creep in the city of Hollister occurs in a zone that varies in width from about 10 feet to 50 feet

(Rogers and Nason, 1971). Right-lateral creep rates along this segment of the fault have varied with respect to both time and location along the fault. The rate of displacement from 1967 to 1971 was 0.4in/yr (Rogers and Nason, 1971, and was observed to be continuing in 1979. Maximum cumulative offset along this trace of the Calaveras fault during the period 1909-1971 was 13 inches of right-lateral strike-slip displacement measured across a concrete sidewalk on the north side of Sixth Street.

Documented fault creep along this trace on the Hollister quadrangle extends southeast from Wright Road to Cienega Road bridge south of the city (figure 3). South of Cienega Road bridge, the fault trace cannot be accurately located. Rogers (1973) shows the trace along the channel of San Benito River, but does not cite evidence for the presence of the fault at this location. Radbruch (1974) does not show an active trace 800 feet south of the bridge. Kilburn (1972) shows a concealed trace based on ground water elevations along a more southerly trend south of the bridge (figure 2). About 2000 feet north of the bridge Kilburn shows a concealed fault that branches southeast from his principal trace (figure 2). Dibblee (1975) shows this fault farther to the west than Rogers (1973) south of the bridge (figure 2). The concealed trace of the fault south of the bridge, as shown by Dibblee, does not seem to offset Holocene or older (late Pleistocene?) alluvial units.

Study of 1966 WRD air photos (USGS) suggests that a discontinuous fault trace may exist 400 feet east of Roger's 1973 main trace south of Nash Road (figure 3). The fault trace, which trends more easterly than Rogers' trace, is delineated by vegetation lineaments. Study of 1939 air photos (U.S. Soil Conservation Service) does not show most of these lineaments, except where noted on figure 3. Field checking in this area did not reveal evidence for faulting.

Terrace deposits exposed east of Cienega Road were not offset near the fault location of Rogers (figure 3). However, much of the river bed and some terrace deposits from Cienega Bridge south to Hospital Road have been mined for sand and gravel, thus obliterating any geomorphic evidence for faulting.

Branch Fault A

One block south of Dunne Park, Rogers (1973) shows a fault branching to the west of the main trace (figure 2). This fault was mapped based on a west-facing scarp trending northwest from Dunne Park and a "significant" gravity anomaly near Vista Road (Rogers, p.c., 1979). North of Vista Road the fault was projected using the base of hill 281 as control (figure 2). No geomorphic evidence has been found for the presence of the fault north of Fourth Street.

Kilburn shows a concealed fault that generally trends parallel with the fault mapped by Rogers, but has located the fault farther to the west (figure 2). The fault trace seems to be offset by an east-west trending fault, but the location of a test well symbol on Kilburn's map obscures the trace at this junction (Kilburn, 1972, figure 3). No evidence is cited for the presence of the fault mapped by Kilburn and this feature does not offset ground water elevations (Kilburn, 1972, figure 5). Dibblee (1975, 1979) does not show this fault.

Based on air photo interpretation by this writer, a west-facing scarp can be followed from Dunne Park northwest to about Fourth Street. The scarp is about 2 to 3 feet high just west of Dunne Park, but diminishes in height along its northwest trend. Northwest of Fourth Street the scarp

cannot be found. Field checking confirms the location of a west-facing scarp southeast from Fourth Street to Dunne Park, but no evidence of deformation of curbs or streets was observed.

Branch Fault B

This fault trace, which trends northwest from the saddle in Park Hill (figure 2), was zoned based on Radbruch (1968). Radbruch's fault location was compiled from mapping by Rogers and Nason (1967). The fault location by Rogers and Nason was based on air photo interpretation (Rogers, 1979, p.c.). No evidence for faulting was observed by Rogers during subsequent field mapping; Rogers' 1973 map does not show this fault.

Kilburn (1972) does not show this fault on the surface and indicates that ground water levels are continuous across the inferred trace of this fault. No surface expression of this fault was observed from interpretation of 1939 (U.S. Soil Conservation Service) and 1966 air photos (U.S.G.S.) by this writer.

Branch Fault C

This segment of the Calaveras fault was zoned based on the location of Radbruch (1968) (figure 2). A revised map by Radbruch (1974) does not show this fault trace. Rogers, whose 1967 map is the basis for Radbruch's 1968 location (Rogers and Nason, 1967), does not show this fault on his 1973 map but instead has mapped a synclinal axis along the trend of the saddle. Kilburn (1972) and Dibblee (1975, 1979) do not show this fault.

Air photo interpretation on 1939 and 1966 photos indicates that faulting may form the saddle. A depression at the southeast end of the saddle may be fault related (figure 3), although it may be localized drainage

closed by road fill. Depressions observed in the saddle of Park Hill during field checking were not clearly related to the road fill and may be fault related.

East Branch Calaveras Fault

Two fault traces of the east branch Calaveras fault are shown on the SSZ Map of the Hollister quadrangle and were zoned based on Radbruch (1968) and Rogers (1973) (figure 2). As mentioned previously, the inferred fault trace of Radbruch (1968) is based on mapping by Rogers and Nason (1967). Based on detailed field mapping, Rogers (1973) relocated the trace of the fault 250 to 300 feet west of the trace shown by Radbruch (1968, 1974) and showed the fault as concealed. Dibblee (1975) shows a concealed easterly trace of the Calaveras fault, the location of which agrees well with Rogers' 1973 location south southeast from Park Hill to the edge of the Hollister 7.5 - minute quadrangel (figure 2).

Kilburn (1972) shows a concealed fault trace that generally coincides with the location of Rogers (1973) from Park Hill south southeast to the east jog of Southside Road (figure 2). Kilburn located the trace of this fault along the west side of hill 668 (figure 2). This fault, as interpreted by Kilburn, offsets the water table by about 20 to 25 feet (east side up) and is a ground water barrier.

Faults located on both sides of hill 668 (figure 2) are based on work by Radburch (1968) and Rogers (1973).

Two site investigations have been conducted along this fault trace (figures 2, 3). Leighton and Associates (1974; AP-56) located a northwest trending fault that offset all units except "the uppermost portion of the soil cover" in two trenches along the east side of hill 668 (figures 2, 3).

The east-west trending fault in hill 668 was also trenched by Leighton and Associates (1974; AP-56) and was found to offset all soil units (figures 2, 3).

A trench excavated 400 feet north of Nash Road by Woodward-Clyde and Associates (1970; 35-18-33072) (figures 2,3) exposed evidence of faulting along the east branch of the Calaveras fault. Silty clay sediments mapped as lake deposits by Rogers (1973) are cut 9 feet below the surface by a "slickensided plane." A sandy silt bed that underlies the silty clay sediments is cut by two to three "clay seams" 1/2 to 3 inches thick that dip steeply to the west.

The age of sediments exposed in this trench is assumed to be Holocene. Core samples of clays in the Hollister Valley have been collected and dated by Herd (1978). The lowermost clays (generally occurring 80 to 90 feet below ground surface) have been C^{14} dated at 9900 years B.P.; uppermost clays are dated at 4,000 years B.P. Four samples were taken from locations along the east side of the main trace of the Calaveras fault from San Felipe Lake (San Felipe 7.5-minute quadrangle) south to the north side of Hollister near Cottage Corners (Herd, p.c., 1979) (figure 3).

The location of the east branch of the Calaveras fault, based on interpretation of 1939 (U.S. Soil Conservation Service) and 1966 (USGS) air photos, coincides closely with Rogers' 1973 location south of Park Hill to hill 668. The fault along the west side of hill 668 can be located about 200 feet northeast of Rogers' 1973 trace. Additional faulting at the south end of hill 668 can be interpreted from 1939 and 1966 air photos (figure 3).

Branch Fault D

A short northwest trending fault along the east side of Park Hill is shown on the Hollister SSZ Map and was zoned based on Radbruch (1968), who based her fault location on Rogers and Nason (1967). A later map by Rogers (1973) deleted this fault trace. No evidence for this fault was observed by Rogers (personal communication, 1979). Evidence for recent faulting was not observed on 1966 air photos (USGS) by this writer.

Branch Fault E

This fault is shown on the Hollister SSZ Map and was zoned based on Radbruch (1968). Radbruch's location was based on fault locations by Rogers and Nason (1967). Rogers projected this fault trace from the east side of a hill on the San Felipe 7.5-minute quadrangle south 1000 feet onto the Hollister 7.5-minute quadrangle (Rogers, p.c., 1979). No evidence of faulting was observed on 1966 aerial photos (USGS) by this writer.

Northeast Trending Fault

A northeast trending fault mapped by Rogers (1973) is located on Cienega Road 800 feet southeast of the abandoned Union School building (figures 2,3). Northeast trending cracks across Cienega Road are located at the base of a small (1 1/2 to 2 inches high) northwest-facing scarp. This feature is not visible on air photos, but during a field check in October 1979 a scarp and cracks across Cienega Road were observed. The cracks extended into gravel shoulder material on either side of the road. Periodic maintenance on the road at this location is required (Bishop, p.c., 1974). Fault features could not be followed northeast or southwest from Cienega Road.

SAN ANDREAS FAULT - Refer to FER-99

"BUENA VISTA ROAD" FAULT

The "Buena Vista Road" fault west of Hollister was zoned based on Rogers' 1973 map (figure 2). Rogers based the location of this feature on reports by property owners that cracks in the ground occurred during the 1906 earthquake. Reports indicate that water issued from a crack; the southeast side was down. A small pond (sag pond?) was reported to exist in 1906 just east of hill 295 (figure 3). A revised map by Rogers (in press) does not show the "Buena Vista Road" fault. Rogers concluded that evidence for surface fault rupture is equivocal and the cause of cracking could also be explained by ground-shaking features such as seismically induced settlement or liquifaction (Rogers, p.c., 1980).

Kilburn (1972) shows a fault with roughly the same general trend as Rogers' fault east of hill 295 (figure 2) and indicates that the fault offsets the water table. The sense of displacement is southside up, but the magnitude of offset is not clear from Kilburn's map and may be less than 10 feet.

The "Buena Vista Road" fault is expressed as a linear tonal contrast (ground water barrier?), based on interpretation of 1939 and 1966 air photos by this writer. The 1966 air photos show a vague lineament, but 1939 air photos show this feature as a stronger tonal contrast extending to hill 281 (figure 3). The fault is expressed in hill 295 as a man-modified bench (figure 3). (Southwest of hill 295 no surface evidence of faulting was observed on air photos or during field checks.)

A buried irrigation line coupling near the trace of the fault has been repeatedly broken, according to property owners. The line was broken during a field check by this writer (8-8-79). Although a M5.9 earthquake had occurred on 8-6-79, the property owner stated that the line had been broken prior to the earthquake.

6. Conclusions

a. Calaveras Fault

(1) West Branch Calaveras Fault: The position and activity of this trace of the Calaveras fault on the Hollister 7.5-minute quadrangle from Wright Road to Cienega Road bridge is well-documented. The trace of this branch of the fault south of Cienega Road bridge is obscure and reliably cannot be followed. The region south of Cienega Road bridge may be the southern terminus of a left-stepping strand of the Calaveras fault. Linear vegetation contrasts south and east of the bridge observed on 1966 air photos (USGS) suggest that the main trace may step east to the west side of hill 668. However, these lineaments are not found on 1939 air photos (U.S. Soil Conservation Service) and were not observed during field checks by this writer. Additional faulting may be present from the bridge southeast to hill 668, but agricultural and mining activities have modified or obliterated geomorphic features.

(2) Branch Fault A: This fault is based on a west-facing scarp joining the main trace of the Calaveras fault and is inferred northwest of 4th Street from geophysical studies (Rogers, p.c., 1979). The presence of a scarp in Holocene-dated deposits (Herd, 1978; p.c., 1979) implies a Holocene active fault. However, the arcuate shape of the scarp may be the result of lateral stream erosion. No evidence of active creep was observed. No evidence for the trace of this fault has been found north of Vista Road, although hill 281 implies a northward projection of the fault.

(3) Branch Fault B: There is no evidence for faulting along the inferred trace of this fault.

(4) Branch Fault C: The trace of this fault is shown on Radbruch's 1968 preliminary map. A revised map by Radbruch (1974) deletes

this trace, and Rogers' 1973 map shows a synclinal axis rather than a fault. A closed depression at the southeast end of the saddle may be the result of road fill blocking normal drainage through the saddle, but additional depressions in the saddle and a linear scarp (?) on the north imply a fault related origin.

(5) East Branch Calaveras Fault: The westernmost trace of the east branch of the Calaveras fault (Rogers, 1973) (figure 2) from Park Hill south has been shown to offset deposits considered to be Holocene in age (Woodward-Clyde & Assoc., 1970; Herd, 1978; Herd, p.c., 1979). The location of this fault can be observed from about 6th Street in Hollister south to the east-west segment of Southside Road. Gravity and ground water information support the location of the fault (Ellis, 1952; Kilburn, 1972; Rogers, 1979, p.c.).

There is no evidence for the existence of the easternmost trace of Radbruch (1968) shown on the SSZ Map of the Hollister quadrangle.

Faults bounding hill 668 generally coincide with the location shown on the SSZ Map, although differences in detail exist (figures 2,3).

(6) Branch Fault D: There is no evidence for faulting along the inferred trace of this fault.

(7) Branch Fault E: There is no evidence for faulting along the inferred trace of this fault.

(8) Northeast Trending Fault: The northeast trending feature in Cienega Road mapped by Rogers (1973) may be related to subsidence due to ground water withdrawal. However, a similar trending feature, the Busch fault located about 8 miles to the north, has been associated with seismic activity (Mortensen and Johnston, 1976).

b. San Andreas Fault: refer to FER-99

c. "Buena Vista Road" Fault: Location of the "Buena Vista Road" fault is based on reports by property owners of cracks in the ground formed during the 1906 earthquake. Additional evidence for the location of the fault includes: (1) the presence of a small lake (sag pond?) in 1906; (2) tonal lineaments on 1939 (U.S. Soil Conservation Service) and 1966 (USGS) air photos; (3) geomorphic expression in hill 295. Most of the evidence is weak. The reported cracks during the 1906 event may have been seismically induced settlement or liquefaction. Continuing damage to an irrigation line coupling may be due to fault creep, but it more likely is caused by subsidence due to ground water withdrawal. However, similar northeast trending faults north and south of this feature (Busch fault (Rogers, 1967) and Northeast Trending Fault (this report)) imply a structural relationship to the "Buena Vista Road" fault.

7. Recommendations

a. Calaveras Fault Zone

(1) West Branch Calaveras Fault: Maintain fault trace as shown on SSZ Map north of Cienega Road bridge. Query fault trace south of the bridge and draw zone sufficiently wide to allow for uncertainties in locations of active trace(s) (figure 4).

(2) Branch Fault A: Maintain fault trace as shown on SSZ Map south of Fourth Street. Delete fault trace north of Fourth Street (figure 4).

(3) Branch Fault B: Delete fault trace.

(4) Branch Fault C: Revise fault location of Radbruch (1968) based on this report (figure 4).

(5) East Branch Calaveras Fault: (a) Delete easternmost trace of Radbruch (1968) (figure 4). (b) Revise location of Rogers' 1973 trace based on work of Woodward-Clyde and Associates (1970) and this report (figure 4). (c) Revise location of fault traces in hill 668 based on Leighton and Associates (1974) and this report (figure 4).

(6) Branch Fault D: Delete fault trace.

(7) Branch Fault E: Delete fault trace.

(8) Northeast Trending Fault: Add fault trace as shown on Rogers' 1973 map. Draw SSZ of the west branch (main trace) of the Calaveras fault to include this fault (figure 4).

b. San Andreas Fault-Refer to FER-99

c. "Buena Vista Road" Fault: Delete the existing SSZ and fault traces.

8. Report prepared by William A. Bryant, 10-19-79.

William A. Bryant

I agree with the recommendations, although the newly proposed SSZ boundaries may need some adjustment.

Elliott
7/24/80

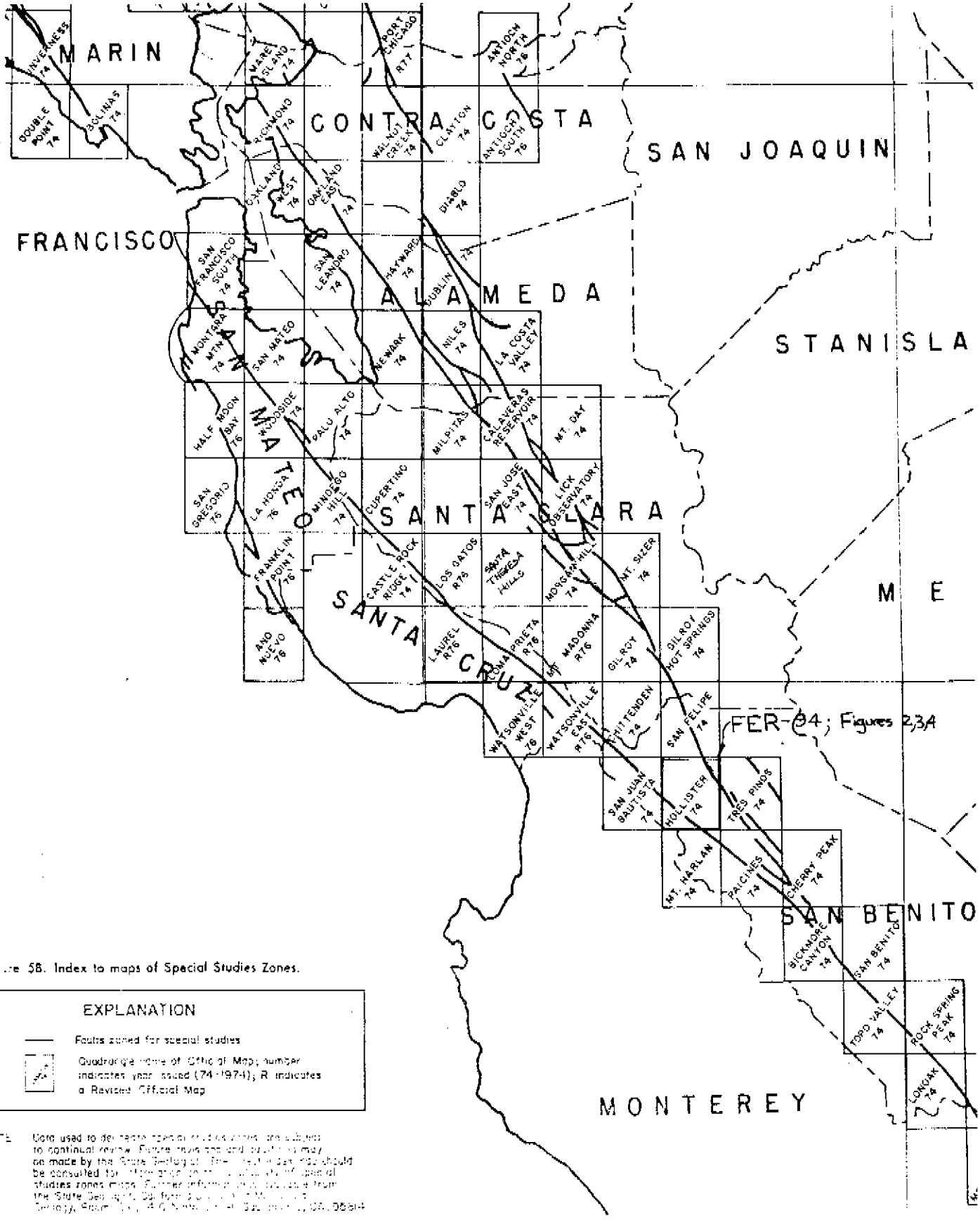

Figure 58. Index to maps of Special Studies Zones.

NOTE: Data used to delineate [illegible] are subject to continual review. Future revisions and additions may be made by the State Geologist. The most current data should be consulted for [illegible] special studies zones maps. Further information may be obtained from the State Geologist, [illegible]

Figure 1 (to FER-94). Index to main faults and Special Studies Zones, Hollister quadrangle (from CDMG Special Publication 42, p.13).